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The Observations by Fabricius and Heller of the Comet of 1556.

Being the substance of a paper by Karl v. Littrow in *Sitzungsberichte Wiener Akad. der Wissenschaften*, vol. xx. p. 301. Translated by the late A. S. Herschel. (Plate 14.)

(*Communicated by Professor G. Forbes, and edited by A. C. D. Crommelin.*)

Prefatory Note.—In the middle of the last century there was general expectation of the return of the comet of 1556, which was assumed to be identical with the comets of 975 and 1264. Accordingly, active search was made for possible further records of its path, which might have escaped notice. Littrow succeeded in finding further particulars concerning the observations of Fabricius, and an important series of observations by Joachim Heller. This new material was utilised by Martin Hoek, a few years later, in his definitive orbit of the comet. In 1908 Professor Forbes published a paper in the *Monthly Notices*, vol. lxix. p. 152, in which he suggested that the comet had encountered his hypothetical trans-Neptunian planet when near its last aphelion passage, and returned in four portions, whose orbits had been changed from direct to retrograde, in the years 1843, 1880, 1882, 1887. He had previously consulted A. S. Herschel, who had prepared for him the translation of Littrow's pamphlet, and also made some calculations of his own on the positions of the comet.

Herschel was evidently unacquainted with Hoek's work, and thought no one had yet utilised Heller's observations. Herschel's manuscript was lately submitted to the Society by Professor Forbes. It has been decided to print it in an abridged form, in view of the interesting questions connected with this comet, and the care with which Heller observed it. I have shortened A. S.

Herschel's paper by the omission of some details of no astronomical importance, and the suppression of many of Heller's circumlocutory descriptions of stars, the modern designation of the star presumably intended being substituted. I have also added some tables at the end, giving the positions of the comet and stars. A. C. D. C.

K. von Littrow, on Observations by P. Fabricius and M. Joachim Heller of the Comet of 1556. Translated from *Sitzungsberichte of Vienna Academy*, vol. xx., by A. S. Herschel.

In deducing the elements of the great comet of 1556, presumably expected to return between 1856 and 1860, all the recent calculators have overlooked the original observations of the Court mathematician of that time, Paul Fabricius. Even Pingré was only acquainted with them from a little chart contained in Conrad Lycosthenes' *Prodigiorum ac ostentorum Chronicon*, and in other works on which were inscribed the comet's places, said to have been observed by Paul Fabricius in Vienna; on these he, as also later calculators, were obliged, through lack of other data, to base their calculations. I do not know whether Halley used any original publications by Fabricius, as I have not access to his *Synopsis of Comets*. Mr. Hind regretted this imperfect knowledge of a source from which useful help in the accurate determination of this body's motion might be expected; he begged me, some two years ago, to search for the original publication of Fabricius. After numerous inquiries among my friends, I resorted to advertisement in the papers of Vienna. I obtained in this manner, through the kindness of Mr. C. Denhart, the first knowledge that modern astronomers have acquired of an original description by Fabricius. In a volume of Royal Patents, preserved in the State archives, there occurs a leaflet with the title "The Comet Seen in March, in the year LVI. in Vienna"; it contains a rough woodcut map of the comet's course, and a dedication to Vito Hütter. This is evidently the map used by Lycosthenes; its scale is three times as large as that of the copy. As the maker of the woodcut did not allow for reversal, the heavens appear reversed right and left in the map. (Littrow corrects this in the copy he gives.) There are seventy-four lines of text, beginning thus: "In my *Pratika*, which I had to make and publish ten months ago for official purposes, it was noted, among other matters, that this year would not pass away without a comet of such magnitude as all may see who have my *Pratika*. Now a comet has just appeared in March in this land of Austria, whose course may be seen in this map, along with the chief stars. It began on the fourth of March, and rose upwards towards midnight, night after night. For further particulars, see my Latin *Judicium*, in which the hours of observation are noted": this is dated 14th March 1556. Following up this clue, with the help of F. Roeth of Augsburg, I found the *Judicium*. It begins, like the pamphlet, with his prediction, and the discovery of the comet: "It was first seen on the ecliptic,

in longitude $8\frac{1}{2}^\circ$ of Libra; it gradually rose, and after . . . nights it passed over Bootes and Ursa Major. The position on March 4 I did not observe, and inserted by guesswork. On March 5, 10^h night, it was as yet small, Longitude $8\frac{1}{2}^\circ$ Libra, Decln. about $+3^\circ$, lat. $+7^\circ$; the 3rd, 4th, 5th, 6th positions were on Mar. 6, 7, 8, 9, the last at 9^h night, the others at 10^h. I observed at the residence of Archduke Charles II. of Austria; 7th position, Mar. 10, 9^h; 8th, Mar. 11, 4^h morning; 9th, Mar. 11, 9^h night; 10th, 3 hours later, when the comet occulted a small star in left arm of Bootes (λ Bootis according to Littrow, Piazzi XIII. 316 according to Hoek); 11th position, Mar. 12, 4^h morning; 12th position, Mar. 12, 9^h night; Mar. 13, no observations, cloudy; Mar. 14, 4^h morning, I could with difficulty, through clouds, see the comet near the two chief stars of Ursa Minor (β, γ). . . . The comet itself is not so very large, about equal to a first magnitude star; it is dull in light, in motion not so swift as Mars or Mercury, with only a moderate tail . . . it turned its tail, when setting, somewhat southwards, having hitherto been along parallels. While this is being printed I have added two further observations, useful for the ninth and tenth problem of Regiomontanus on comets; the first near the pole of the zodiac, Mar. 14, 9^h night; the other near the shoulder of Cepheus, Mar. 15, 9^h; the comet was then smaller than before; on Mar. 16 it had advanced a little, and was so small that it was barely visible."

Some of this account is lost through injury to the page, some is omitted here, as being of no astronomical importance. We now have access to all that we can hope to learn about the work of Fabricius on this comet. First, he did not pursue his observations later than March 15, and his position for March 4 was merely a guess, so that his observations extended over only eleven days. Secondly, we gain no more exact positions of the comet than what we can read from the map, of which the inexactitude is very obvious. Lastly, the hours of the observations, which are the chief new matter supplied by the *Judicium*, are evidently only given in round figures. Still, these two new documents are a welcome completion of an astronomical observation of the sixteenth century, and the occultation of the star in Bootes may prove useful.

A third source of information, which I have nowhere seen mentioned, appears to me to provide the best materials for calculation, not excepting Fabricius. Dr. Bethmann, librarian at Wolfsbüttel, drew my attention to this work: *Pratika for* 1557, *with an exposition of what the appearance and motion of the recently observed comet* (which was previously predicted) *in the year* '56 *resembled and signified, by M. Joachim Heller, Astronomical Preceptor in Nürnberg.* In the fourth chapter of this work Heller speaks of having predicted the comet's appearance, and then proceeds as follows: ". . . which actually happened soon after the Full Moon in February, for having watched for a favourable sky for many evenings in my journey,

and perceived nothing but a brightly clear sky on the first two days and nights, on the third evening after, which followed the Thursday after S. Matthias, having ridden after 6 p.m. to the Gefress (according to Stieler's map, 9° 24′ E. of Paris, 50° 5′ N. Lat.), finding myself belated at night on the hills behind Berneck (4′ W. 2′ S. of last station), I saw the Moon rise $2^h\ 20^m$ after sunset, Spica Virginis 24^m later; near the latter star, but nearly 3° nearer the south, under Spica, towards the tail of Corvus, a great fiery unusual-looking star, following in the moon in its rising, though I had never before seen any such star at that place, & though I well knew that all other planets had set near the sun, and that Jupiter was very far below the horizon. For a time I was somewhat doubtful, as I could so far see no tail to the comet. But on arriving, still doubtful, at Nürnberg, I learnt after Mar. 3 that people there had seen a comet with a little tail on Mar. 3; while respectable, trustworthy people assured me that, with many others, they had seen the unusual star in that shape from the first, on the above-mentioned Thursday after St. Matthias [this Thursday would be Feb. 27]. Hence I am no longer now in doubt about the place where the comet first broke out, or kindled; just as in that kind of body I have before prognosticated. When the 4th and 5th nights became dark, I betook myself with instruments to observation, and found it on the next following night, which followed Mar. 6, a little over 2 hours after sunset, risen several degrees above the horizon; it extended its tail between west and south, and its head, or beginning in front, was still red, but the tail was of mingled pale and dingy colour, such as the flame of burning sulphur usually presents. [Some matter is omitted here.]

"As regards this comet's course, I was careful to note it, either at its rising, or on the meridian, or by known stars, as certain reference-points of its visible position in the sky. And at its first appearance, on the night of Feb. 27, it rose exactly with Spica, though in my judgment it was 3°·4 to the south of it in latitude. Then as the comet in rising was on the same level with Spica, so I also saw over the comet the small star (ψ Virginis) which is the last of the 3 under Virgo's left shoulder, and I judged the comet to be nearly midway between (ψ) and (Piazzi XIII. 9) the first of the 3 small stars (Herschel says x, P, K Virginis, using Bode's nomenclature) that lie below Spica, behind the tail of Corvus; from this I infer that the comet first appeared in Longitude Libra 15°·83, S. Lat. 5°·4; it rose at the same time with R.A. 205°·9, Decl. 0°, and with Long. Libra 18°·67; then on Mar. 6, when it appeared with its tail as above described, I found it had moved nearly 15° higher in Lat., & about 9° in Long.; and again when I noted it in the Observatory, 52^m after midnight, I compared it with the 8th star of Virgo (k Virginis), which preceded it by 3^m of R.A., and with the 9th star (θ Virginis) which followed it by 10^m of R.A., and it stretched its tail downwards to near the 10th star of Virgo (δ Virginis), which came to the meridian 5^m

before the comet; comet's Long. then Libra 6°, Lat. 10° N. On the next night, Sat. Mar. 7, comet a little above Vindemiatrix (ϵ Virg.), projecting its tail downwards towards the next star below that on the wing of Virgo (σ or *e* Virg.); at 10^h its distance from Vind^x was nearly 3°; so I waited till midnight, and then noted Vind^x nearly $2\frac{1}{4}°$ in Long. from the comet, and about $\frac{1}{3}°$ below it; at $12\frac{3}{4}^h$ the star reached meridian in R.A. 189°; 10^m later the comet reached meridian, R.A. $191\frac{1}{4}°$, $\frac{1}{3}°$ higher; afterwards at $13^h\ 12^m$ Spica reached meridian, R.A. 195° 25′; & I found the comet $21\frac{3}{4}°$ N. of that star in Decl.; Sun's R.A. at midnight $357\frac{1}{4}°$. From this observation I found comet's place at midnight, Long. Libra 5°, N. Lat. $16\frac{1}{3}°$, or R.A. 191°, N. Decl. 12°·7. On night of Mar. 8, at $13^h\ 3^m$, I again observed comet with Spica on meridian, above which star it stood 29°·9 in Decl. Spica followed it by 6^m in R.A. on meridian; thus comet was $8\frac{1}{8}°$ higher in Decl. than night before, with R.A. 194°; and $\frac{1}{4}°$ above (τ) Bootis in Decl., which reached meridian about $13^h\ 40^m$ or 36^m after comet; at midnight on this night comet's Long. Libra 4°, N. Lat. $24\frac{5}{8}°$; on night of Mar. 9 comet crossed meridian at $1\frac{1}{4}^h$ after midnight; Spica reached meridian with $198\frac{1}{4}°$ (Herschel notes 'query meaning of this, Spica's true R.A. was 195°·5; probably Heller's instruments were out of adjustment'), Spica was 10^m of R.A. before comet, & $39\frac{1}{3}°$ S. of it in Decl., *i.e.* comet's N. Decl. was $30\frac{1}{2}°$. *a* Coronæ followed the comet by 2^h, and was 2° S. of it in Decl. Arcturus followed comet by $\frac{3}{4}^h$, exactly at 2^h a.m.; it was $8\frac{3}{4}°$ south in Decl. On night of Mar. 10 the comet crossed meridian between 1^h & 2^h after midnight, exactly 38° N. of equator, 16° 10′ higher than Arcturus, which followed it by a little less than $\frac{1}{2}^h$ on meridian, at $1^h\ 56^m$. On night of Mar. 11 I saw comet on meridian $1^h\ 57^m$ after midnight, and star (λ) Bootis at left elbow of Bootes was 4′ above it and 20′ behind it. It passed nearly through Zenith of Nürnberg, and from its position in front of the shafts of the Wain, it seemed to wish to draw it; (η Urs. Maj. preceded comet by 29^m, $3\frac{1}{2}°$ above it in decl.). On night of Mar. 12 it had risen in meridian to $10\frac{1}{2}°$ beyond the Zenith of Nürnberg, and lay near the last of the 3 stars in last bend of Draco's tail (ι Draconis); this star was $\frac{1}{2}°$ north of the comet, & followed it by $12^m\ 40^s$ on meridian. On night of Mar. 13 it had crossed N. Polar Circle, and at 4^h after midnight it formed apex of an isosceles triangle with legs 6° long from γ and η Ursæ Minoris towards Pole of Ecliptic. On following night of Mar. 14 it had moved with rapid speed across star-throng of Draco, from sign of Leo to that of Taurus; and on Mar. 16 to end of sign Aries, near β Cephei, which it in fact occulted. On Mar. 17 comet near ι Cephei. Next night cloudy; on 19th near a star in Cassiopeia's left hand (? Groombridge 4023, Hoek). On 20th it occulted ζ Cassiopeiæ (Hoek says δ Cephei). Next successful observation early on last day of March, near (B Andromedæ) Hand of Andromeda. I found it on Apr. 1 under right hand of Andromeda

(about π Cassiopeiæ) (*sic*; I suppose π Andromedæ is meant). On Apr. 2 it rose $6\frac{1}{4}^h$ after sunset, 55^m after midnight, being at $6\frac{3}{4}^h$ after sunset (shortly after 1^h a.m.), between the stars ρ and σ Andromedæ. On 4th it rose $6\frac{1}{2}^h$ after sunset, 40^m before α Andromedæ, in 3° higher N. Lat. than that star; since the beginning of Apr. it had moved only 3° in Lat. but more in Long. On 5th (Easter Sunday) it rose $6\frac{5}{8}^h$ after sunset, $\frac{1}{4}^h$ before α Andromedæ, was 7° before that star, & stood just 5° quite straight above δ Andromedæ. On Apr. 6 the comet rose $6\frac{3}{4}^h$ after sunset, $5\frac{1}{2}°$ before α Andromedæ, & was $1\frac{1}{2}°$ in Long., 2° in Lat. from δ Andromedæ. On Apr. 7 it rose $6^h\ 50^m$ after sunset, & appeared to have reached stationary point. It is now 2° in Long. & 2° in Lat. from δ Andromedæ."

(Littrow notes that after this Heller's star-descriptions became difficult to follow, and their identification provisional.) "On Apr. 8 comet rose $6^h\ 55^m$ after sunset, & was then $\frac{7}{8}°$ from (Hoek) π Andromedæ (Littrow says Pi. o, 86), & about 2° from δ Andromedæ (Hoek) (Littrow says ϵ Andromedæ). On Apr. 9 it rose 7^h after sunset, & was 5° in Long. from α Andromedæ, $\frac{1}{2}°$ lower in Lat.: still about 1° above δ Andromedæ. On Apr. 10 it rose $7^h\ 5^m$ after sunset, 12′ downwards from δ Andromedæ. Apr. 11 cloudy. On Apr. 12 it made an isosceles triangle with δ Andromedæ & ϵ Andromedæ (Littrow says Piazzi o, 122) lying towards α Andromedæ, $\frac{2}{3}°$ from that pair of stars. On Apr. 13 it had moved to 1° 10′ below δ Andromedæ, downwards, & $\frac{1}{2}°$ towards α Andromedæ. On Apr. 14 it lay 25′ under ϵ Andromedæ in Lat., & about $\frac{1}{4}°$ from that star towards α Andromedæ, being then $2\frac{1}{2}°$ under δ Andromedæ & 8° from α Andromedæ. On Apr. 15 the comet lay as far beyond δ Andromedæ as that is from π Andromedæ, in same straight line with both stars. On Apr. 16 it had moved from last place 13′ S. in Lat. & 32′ in Long. On Apr. 17 it was twice as far from the lower shoulder star of Andromeda, ϵ Andromedæ, as the upper one, π Andromedæ, is from the middle shoulder star, δ Andromedæ, but laterally 50′ nearer to the tropic of Cancer; it thus lay nearly midway in an isosceles triangle from ϵ Andromedæ & i Piscium. On Apr. 19 it reached the Tropic of Cancer, at $1\frac{1}{2}°$ from η Andromedæ.

"After this date I could no longer observe it, as although I glimpsed it once with difficulty in the nights that followed, until Apr. 22, the view was insufficient, as the stars were also fading out near the approaching sun, to permit a sure observation of it. I trust, however, that the learned will have particulars enough in this account for calculating the comet's real course."

Addendum by A. C. D. Crommelin.

This ends the extract from Heller's account. The modern names of the stars are, of course, later additions. Littrow remarks that Heller's observations have a range of 53 days. He draws attention to the three star-occultations of Mar. 11, 16, 20.

It was by planetary conjunctions that Fabricius and Heller were led to predict a comet in 1556. He adds that astrological prediction was then the main motive for making careful cometary observations, but suggests that this may be pardoned in view of the useful records which they have handed down to us. All attempts to identify the exact spot at Nürnberg where Heller observed have been unsuccessful.

Herschel ends his paper with a list of cometary places deduced by him from Heller's record. I print this in conjunction with Hoek's places. The latter appear to be more reliable; several of Herschel's star places for 1556 are in error, as the appended table shows, and in some cases Hoek has altered the identification of the stars.

The following is Hoek's final orbit:

$$\left.\begin{aligned} T &= 1556 \text{ April } 22{\cdot}1846 \text{ G.M.T.} \\ \omega &= 100^\circ\ 52'{\cdot}6 \\ \Omega &= 175^\circ\ 13'{\cdot}9 \\ i &= 32^\circ\ 25'{\cdot}7 \end{aligned}\right\} 1556{\cdot}0$$

$$\log q = 9{\cdot}69092$$

$$\begin{aligned} x &= [9{\cdot}99956]r \sin (v + 6^\circ\ 50'{\cdot}95) \\ y &= [9{\cdot}99481]r \sin (v + 276^\circ\ 27'{\cdot}11) \\ z &= [9{\cdot}20386]r \sin (v + 112^\circ\ 50'{\cdot}29) \end{aligned}$$

From these elements I computed the appended ephemeris; I assumed for the G.M.T. of Equinox 1556 March 10·209, which is in almost perfect agreement with Grattan Guinness's value. The obliquity of ecliptic was 23°·496.

Ephemeris of the Comet from Hoek's Final Elements and Comparison with Observed Places.

G.M.T.	Calculated. R.A.	Dec.	Log r.	Log Δ.	Calculated − Observed. R.A.	Dec.	
1556 Feb. 27·37	186°·77	−9°·07	0·1058	9·4746	− 2°·97	+1°·33	H_2
Mar. 5·38	191·01	+4·21	·0632	9·1972	− ·10	+1·41	F
6·38	192·17	7·96	·0567	9·1703	− ·71	− ·19	F
6·51	192·36	8·53	·0558	9·1630	+ 2·81	+1·33	H_2
7·38	193·70	12·73	·0500	9·1192	− 1·23	− ·78	F
7·51	193·93	13·44	·0491	9·1122	+ 1·98	+ ·09	H_2
8·38	195·62	18·72	·0433	9·0677	− 1·55	−1·74	F
8·52	195·93	19·70	·0423	9·0590	+ 2·33	− ·97	H_2
9·34	198·20	25·95	·0367	9·0169	− 2·21	−1·08	F
9·53	198·90	27·50	·0354	9·0087	+ ·95	−3·02	H_2
10·34	202·00	35·27	·0298	8·9708	− 1·99	− ·80	F
10·54	202·92	37·27	·0284	8·9637	+ ·07	− ·41	H_2
10·63	203·47	38·39	·0277	8·9589	− 1·82	− ·73	F

Ephemeris of the Comet from Hoek's Final Elements and Comparison with Observed Places—continued.

G.M.T.	Calculated. R.A.	Dec.	Log *r*.	Log Δ.	Calculated – Observed. R.A.	Dec.	
1556 Mar. 11·34	208°·11	+46°·30	0·0227	8·9361	+ °·18	+ °·79	F
11·46	209·14	47·69	·0218	8·9330	+ ·81	+ ·12	F
11·55	209·85	48·77	·0211	8·9312	− ·10	+ ·19	H_2
11·63	210·48	49·71	·0206	8·9298	− ·45	−1·05	F
12·34	218·38	58·09	·0155	8·9218	+ ·33	+ ·51	F
12·60	222·31	60·94	·0136	8·9217	− 3·17	+ ·99	H_2
13·63	247·13	70·39	·0059	8·9376	+11·14	+ ·01	F
13·64	247·43	70·40	·0058	8·9378	+ 1·42	−1·20	H_2
14·34	273·48	73·26	0·0006	8·9613	− 4·62	− ·58	F
15·80	317·39	69·47	9·9896	9·0276	− 3·16	+ ·64	H_2
17·51	337·73	60·72	·9760	9·1158	− ·77	−3·18	H_1
19·51	346·42	53·21	·9600	9·2117			
20·51	348·80	50·24	·9516	9·2560			
30·63	357·75	35·60	·8595	9·5725	− 1·95	−4·60	H_1
Apr. 1·51	358·50	34·14	·8411	9·6148	− ·70	−3·06	H_1
2·51	358·89	33·41	·8312	9·6361	− ·44	−1·49	H_2
4·53	359·70	32·04	·8111	9·6770	calc. lat. +29°·22, obs. +29°·0		H_1
5·51	0·04	31·46	·8014	9·6954	− 1·30	− ·89	H_2
6·51	0·47	30·83	·7914	9·7141	− 1·73	+1·38	H_2
7·51	0·89	30·22	·7816	9·7323	− ·96	+ ·83	H_2
8·51	1·36	29·64	·7717	9·7498	− 1·61	−1·01	H_2
9·52	1·77	29·08	·7624	9·7670	+ ·73	+ ·43	H_2
10·53	2·25	28·51	·7530	9·7836	− 1·35	+ ·35	H_2
12·53	3·25	27·43	·7357	9·8156	− ·60	− ·14	H_2
13·54	3·80	26·90	·7277	9·8311	+ ·15	− ·42	H_2
14·55	4·35	26·35	·7202	9·8467	+ 1·13	+ ·32	H_2
15·56	4·96	25·83	·7134	9·8610	+ ·78	+ ·48	H_2
16·56	5·57	25·32	·7074	9·8754	+ 1·10	− ·03	H_2
19·57	7·63	+23·83	9·6946	9·9161	+ ·66	+1·93	H_2

F stands for the observation of Fabricius as interpreted by Hoek.
H_2 ,, ,, Heller ,, ,, Hoek.
H_1 ,, ,, Heller ,, ,, Herschel.

Positions for 1556·0 *of the Stars used for Comparison or mentioned in the Narrative.*

Star's Name.	Alternative Designations.	Mag.	Positions from Boss P.G.C.		Positions adopted by Herschel.	
			R.A.	Dec.	R.A.	Dec.
			h. m.	° ′	h. m.	° ′
28 Andromedæ	Piazzi 0, 86	5·3	1·74	+27·29		
ζ Cassiopeiæ		3·8	3·21	+51·44		
Piazzi 0, 122		6·7	3·28	+24·80		
π Andromedæ		4·4	3·37	+31·26		
ϵ Andromedæ		4·5	3·84	+26·88	3·8	+26·9
δ Andromedæ		3·4	3·97	+28·41		
π Cassiopeiæ		5·2	4·85	+44·58	4·9	+44 6
i Piscium		5·7	6·58	+25·27	6·5	+25·3
η Andromedæ		4·6	8·43	+21·00	8·4	+21·0
q Virginis		5·6	182·75	− 6·99	182·86	− 7·00
χ Virginis		4·8	184·11	− 5·54	184·33	− 5·54
ψ Virginis		5·0	187·85	− 7·10	187·85	− 7·12
δ Virginis		3·6	188·32	+ 5·83	188·2	+ 5·2
k Virginis		6·0	189·21	− 1·39	189·7	− 1·4
ϵ Virginis	Vindemiatrix	2·8	190·02	+13·37	189·9	+13·3
θ Virginis		4·4	191·77	− 3·14	191·7	− 3·2
53 Virginis	*x* Virg. = Pi. XIII. 9	5·2	192·15	−13·77	191·3	−13·5
e Virginis		5·4	193·69	+11·77		
σ Virginis		5·0	193·81	+ 7·84		
61 Virginis	K Virginis	4·8	193·84	−15·81	192·95	−15·60
α Virginis	Spica	0·9	195·49	− 8·81	195·50	− 8·83
69 Virginis	P Virginis	5·0	195·99	−13·63	195·16	−13·35
τ Bootis		4·6	201·54	+19·88	201·5	+19·8
η Urs. Maj.		1·8	202·48	+51·56	202·5	+51·5
Piazzi XIII. 316		5·6	207·53	+42·71		
α Bootis	Arcturus	0·0	208·86	+21·54	208·45	+21·4
λ Bootis		4·2	209·86	+48·17	209·8	+48·2
β Urs. Min.		2·0	223·31	+75·97		
ι Draconis		3·4	228·79	+60·56	228·8	+60·5
α Coronæ	Alphecca	2·2	228·98	+28·27	229·0	+28·2
γ Urs. Min.		2·9	230·59	+73·41		
ζ Urs. Min.		4·3	240·26	+79·11		
η Urs. Min.		5·2	247·97	+76·73		
β Cephei		3·3	320·37	+68·63	320·6	+68·5
δ Cephei		3·7–4·9	333·22	+56·17		
ι Cephei		3·6	338·54	+63·88	338·5	+63·9
Bradley 3084	Groombridge 4023	5·8	344·21	+50·84		
α Andromedæ		2·0	356·42	+26·64	356·4	+26·7
22 Andromedæ	B Andromedæ	5·2	356·91	+43·60	356·9	+43·7
σ Andromedæ		4·6	358·78	+34·32	358·8	+34·3
ρ Andromedæ		5·3	359·52	+35·50	359·5	+35·5

The star Piazzi 0, 122 is not in Boss; its place is from Greenwich 1910.

Herschel's (1) *and Hoek's* (2) *Determinations of the R.A. and Dec. of the Comet, from their Independent Interpretations of Heller's Observations.*

G.M.T.	R.A. (1.)	R.A. (2.)	Dec. (1.)	Dec. (2.)	Stars used by Herschel.
1556					
Feb. 27·37	191°·8	189°·74	−11°·1	−10°·4	ψ Virg., Pi. XIII. 9, Heller's place.
Mar. 6·51	189·0	189·55	+ 7·2	+ 7·2	δ, ε, *k* Virg., Heller's place.
7·51	191·45	191·95	+12·8	+13·35	α, ε Virg., Heller's place.
8·52	193·2	193·6	+20·9	+20·67	α Virg., τ Bootis, Heller's place.
9·53	197·8	197·95	+29·8	+30·52	α Virg., α Coronæ, α Bootis.
10·54	201·7	202·85	+37·9	+37·68	α Bootis, Heller's place.
11·55	209·4	209·95	+48·2	+48·58	λ Bootis occulted, η Urs. Maj.
12·60	225·7	225·48	+60·0	+59·95	ι Drac.
13·64	247·2	246·01	+71·6	+71·60	γ, ζ Urs. Min.
15·80	320·6	320·55	+68·5	+68·83	β Cephei occulted. Herschel takes date as March 16.
17	338·5		+63·9		ι Ceph.
19					Near a star in left hand of Cassiopeia. Hoek says perhaps Groom. 4023.
20	4·4		+48·1		(ζ Cass.) occulted. Hoek says δ Cephei.
30·63	359·7		+40·2		B Androm.
Apr. 1	359·2		+37·2		B Androm., π Cassiop.
2·51	359·2	359·33	+34·9	+34·90	ρ, σ Androm.
4·53					Latitude +29°·0.
5·51	1·2	1·40	+32·9	+32·35	δ Androm.
6·51	1·7	2·20	+29·9	+29·45	δ Androm.
7·51	1·3	1·85	+29·7	+29·39	δ Androm.
8·51		2·97		+30·65	
9·52	1·0	1·04	+28·05	+28·65	α, ε Androm.
10·53	3·8	3·60	+26·7	+28·16	ε Androm.
12·53		3·85		+27·57	
13·54	3·3	3·65	+25·8	+27·32	ε Androm.
14·55	3·6	3·22	+25·5	+26·03	α, ε Androm., Pi. 0, 122.
15·56		4·18		+25·35	
16·56		4·47		+25·35	
19·57		6·97		+21·90	

Hoek's Determination of the R.A. and Dec. of the Comet from Fabricius's Diagram and Description.

G.M.T.	R.A.	Dec.	G.M.T.	R.A.	Dec.
1556			1556		
Mar. 5·38	191°·11	+ 2°·80	Mar. 10·63	205°·29	+39°·12
6·38	192·88	+ 8·15	11·34	207·93	+45·51
7·38	194·93	+13·51	11·40	208·33	+47·57
8·38	197·17	+20·46	11·63	210·93	+50·76
9·34	200·41	+27·03	12·34	218·05	+57·58
10·34	203·99	+34·47	13·63	235·99	+70·40
			14·34	278·10	+73·84

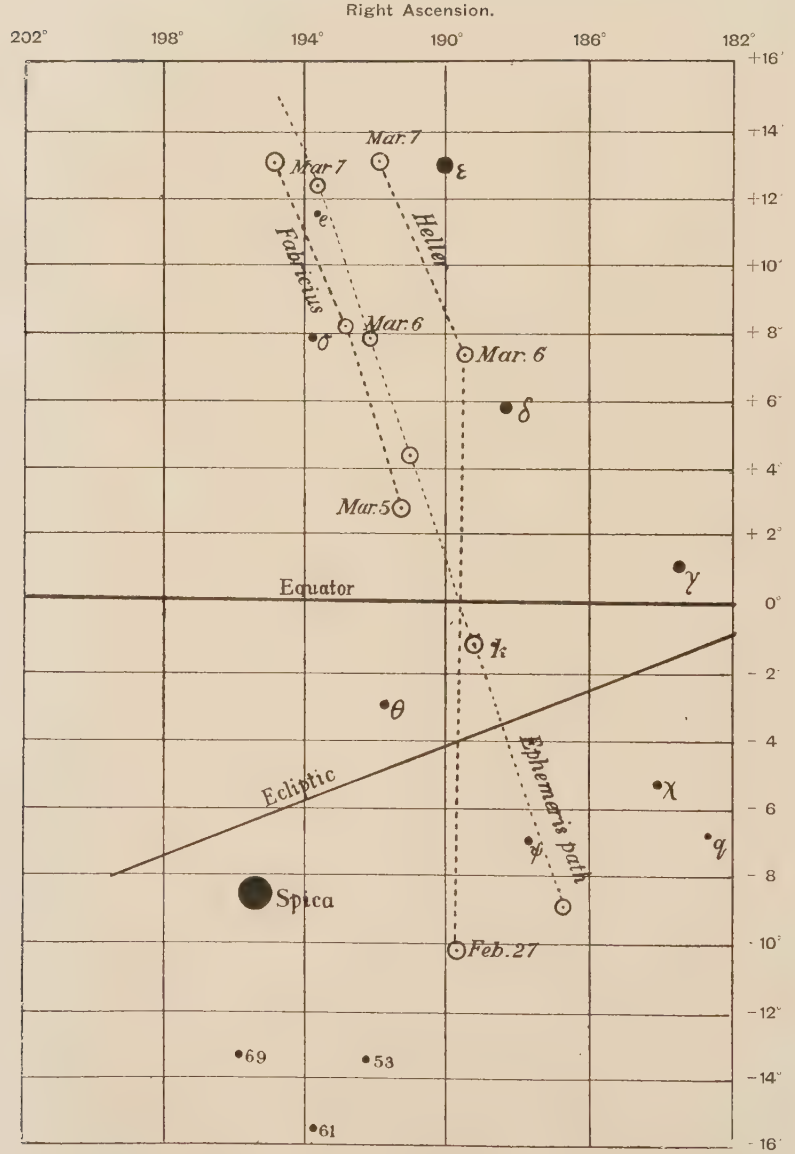


Diagram illustrating the observed and tabular paths of the Comet of 1556 in Virgo.

Comparison of Heller's and Fabricius's Observations when made on the same day (Hoek's Determination).

(The correction for motion has been applied.)

Day.	Heller – Fabricius. R.A.	Heller – Fabricius. Dec.	Day.	Heller – Fabricius. R.A.	Heller – Fabricius. Dec.
Mar. 6	−3°·60	−1°·48	Mar. 10	−2°·09	+0°·30
7	−3·16	−0·77	11	+0·24	−0·17
8	−3·85	−0·61	12	+2·65	−0·55
9	−3·18	+2·08	13	+9·70	+1·13

The places of Fabricius are simply deduced from the path of the comet drawn on his chart. It is clear that this method is more subject to systematic error than Heller's star comparisons, which were made independently each night. The discordance on March 13 is only 3° when reduced to great circle.

The following are some points calling for note:—

(1) The considerable difference in the paths of Fabricius and Heller in the Virgo region. Heller's path is some three degrees further west; his careful comparisons with stars inspire more confidence than the rough chart of Fabricius, and perhaps Hoek should have given a higher relative weight to his observations. (See Plate 14.)

(2) With reference to the occultation of a star in Cepheus, Hoek says it was probably β Cephei.

(3) On March 19 the comet was "near the outermost star in the left hand of Cassiopeia." It is concluded that the right hand is meant. Hoek adopts (though with doubt) the star Bradley 3084.

(4) March 20: Hoek concludes that the head of Cepheus is meant, not that of Cassiopeia.

(5) There seems to be no doubt that Hoek is right in taking the upper, middle, and lower stars in the shoulder of Andromeda to be π, δ, and ϵ. Littrow (followed by Herschel) took them to be Pi. 0, 86; ϵ Andromedæ, Pi. 0, 122. The last is of magnitude 6·7, and is certainly too faint for Heller to have used. The error in the comet's position due to this wrong assumption is about a degree.

The Orbit Elements of Mellish's Comet (1917*a*).

By C. J. Merfield.

The following preliminary elements were deduced from Melbourne observations, 1917 April 19, April 23, May 1

$$T = 1917 \text{ April } 10{\cdot}66871 \text{ G.M.T.}$$

$$\left.\begin{aligned} \omega &= 120^\circ\ 54'\ 4'' \\ \Omega &= 88\ 16\ 56 \\ \iota &= 32\ 44\ 38 \end{aligned}\right\} 1917 \qquad \log q = 9{\cdot}2765052.$$

Residuals.

		$\cos\delta da$.	$d\delta$.
		s	″
March	22·00	−63·1	+149·7
,,	27·00	−46·7	+180·9
April	19·32	− 0·1	− 0·5
,,	23·32	+ 2·5	− 34·4
May	1·31	0·0	+ 0·4
,,	10·32	− 9·6	+ 29·3

The positions for 1917 March 22, March 27, were taken from some positions published in a recent Lick Observatory Bulletin, and are normal places to which I give a weight of four each. The comparison of a position, calculated from the Lick elements, with an observation on May 10, gives the residuals

$$\cos\delta da = +183^{s}, \qquad d\delta = -552''.$$

With my elements as a basis, I set up a system of condition equations; the solution of these gave the following elliptical elements:—

$T = 1917$ April 10·683694 G.M.T.

$\omega = 121^{\circ}\ 20'\ 55''$
$\Omega = 87\ 24\ 37$ } 1917
$\iota = 32\ 28\ 16$

$\log q = 9{\cdot}2787499.$
$\log e = 9{\cdot}9974490.$
$e = 0{\cdot}9941434.$
Period 184·8 years.

Residuals.

1917.		$\cos\delta da$.	$d\delta$.
		s	″
March	22	−0·17	+14·4
,,	27	+1·35	− 7·6
April	19	+0·36	−11·7
,,	23	−3·22	−22·1
May	1	−6·20	−35·1
,,	10	+6·23	+28·3

With these elliptical elements I am now setting up a new system of conditions. The solution will, I hope, considerably reduce the residuals, and result in a system of orbit elements that will require very little modification.

The original elements being so far from the truth, the differential coefficients in the equations of condition require a little correction; and further, the second terms, I find, are appreciable. The elliptical elements herewith will, however, require but small corrections to make the calculation and observation agree.

Assuming the eccentricity to be unity, and finding the elements from the condition equations under this assumption, I obtain the following:—

$T = 1917$ April 10·675588 G.M.T.

$\omega = 121^\circ\ 40'\ 53''$
$\Omega = 87\ \ 0\ 25$ } 1917 $\log q = 9{\cdot}2746037.$
$\iota = 32\ 22\ 40$

Parabolic Residuals.

1917.	$\cos\delta d\alpha$.	$d\delta$.
	s	″
March 22	− 2·87	− 99·3
,, 27	− 7·37	+ 74·4
April 19	−14·50	+348·0
,, 23	− 7·20	+228·5
May 1	+11·06	+ 94·7
,, 10	+17·54	− 28·0

Melbourne:
1917 *June* 20.

Addendum, 1917 *July* 1.

A new solution has been made, adopting the above elliptical elements as the elements to be corrected. The results are as follows:—

$T = 1917$ April 10·688263 G.M.T.

$\omega = 121^\circ\ 21'\ 47''{\cdot}75$
$\Omega = 87\ 23\ 10\ {\cdot}36$ } 1917 $\log q = 9{\cdot}2786202.$
$\iota = 32\ 37\ 57\ {\cdot}24$ $\log e = 9{\cdot}9974886.$
$\log a = 1{\cdot}5177493.$

$P = 189^y \pm$

Co-ordinates.

$x = [9{\cdot}9255725]r \sin(298^\circ\ 15'\ 37''{\cdot}52 + v).$
$y = [9{\cdot}9702722]r \sin(222\ \ 26\ \ 12\ \ {\cdot}55 + v).$
$z = [9{\cdot}8106553]r \sin(159\ \ 17\ \ 57\ \ {\cdot}62 + v).$

Observed Errors of Hansen's Tables as modified by Prof. Newcomb and of Delaunay's New Tables, from Observations made at Greenwich with the Transit-Circle and Altazimuth for the Year 1915.

(*Communicated by the Astronomer Royal.*)

The following table is based on the observations of the Moon's limbs and the crater Mösting A made with the transit-circle and alt-azimuth. The transit-circle was out of use from January to March

during the mounting of a travelling micrometer. A mean error has been found for each day from the combined results of limb and crater observations with the two instruments.

As is well known, the *Nautical Almanac* gives the Hansen-Newcomb position of the Moon. The places from the new Delaunay theory are taken from pp. 690–692 of the *Connaissance des Temps* for 1915.

The observations at Greenwich were reduced with the *N.A.* value of the parallax and semi-diameter. The former is in the mean, 0″·47 and the latter 0″·49 greater than the values used by Delaunay.

Date 1915.			Errors of R.A.		Errors of N.P.D.	
			N.A.	Delaunay.	*N.A.*	Delaunay.
	d	h	s	s	″	″
Jan.	1	12	−0·99	−0·33	−1·0	−1·1
	2	13	−0·84	−0·22	+0·6	+1·0
	5	16	−0·59	−0·06	−3·7	−2·2
	8	18	−0·70	−0·13	−2·5	−1·4
	9	19	−0·63	−0·03		
	10	20	−0·76	−0·14		
Feb.	2	14	−0·75	−0·17	−3·4	−1·2
	3	15	−0·71	−0·16	−3·8	−1·7
	4	16	−0·72	−0·19	−2·0	−0·3
	7	19	−0·79	−0·21	−0.4	−1·4
Feb.	19	4	−0·73	−0·04	+2·6	−1·1
	21	6	−1·25	−0·49	−0·9	−3·5
	24	8	−1·25	−0·45	−0·8	−1·0
	27	11	−1·11	−0·39		
Mar.	1	12	−0·67	−0·00		
	5	16	−0·67	−0·07	−1·6	−0·8
Mar.	19	3	−0·97	−0·29	+3·5	+0·3
	21	4	−1·18	−0·41	+3·4	+1·6
	23	6	−1·17	−0·35	+1·7	+1·7
	25	8	−0·93	−0·16	−3·1	−1·9
	27	9	−0·88	−0·20	−2·0	−0·2
	29	11	−0·83	−0·19	−5·7	−4·3
	31	13	−0·83	−0·20	−3·6	−2·6
Apr.	5	18	−0·74	−0·20	+1·5	−1·3
	7	20			−2·1	−5·8
Apr.	17	2	−0·73	+0·02	+3·5	+0·9
	18	3	−1·06	−0·27	+0·9	−0·9
	21	6	−1·25	−0·38	−2·5	−1·3

Date 1915.			Errors of R.A.		Errors of N.P.D.	
			N.A.	Delaunay.	*N.A.*	Delaunay.
	d	h	s	s	″	″
Apr.	23	7	−1·04	−0·23	−5·2	−3·1
	24	8	−0·92	−0·17	−3·3	−1·1
	26	10	−0·90	−0·27	−6·5	−4·7
	27	10	−0·82	−0·22	−5·9	−4·4
	28	11	−0·71	−0·10	−3·5	−2·6
	29	12	−0·75	−0·14	−3·8	−3·6
	30	13	−0·84	−0·23	−2·8	−3·1
May	1	14	−0·87	−0·25	−4·0	−4·8
	2	15	−0·57	+0·03	−1·0	−2·8
	5	18	−0·61	−0·16	+4·7	+1·2
	7	20	−0·97	−0·56	+0·7	−3·0
	8	21	−0·50	−0·07	+4·8	+0·9
May	19	5	−1·17	−0·30	−1·9	−0·3
	22	7	−0·99	−0·14	−5·2	−2·1
	23	7	−0·96	−0·16	−6·2	−3·3
	24	8			−5·7	−3·2
	25	9	−1·01	−0·33	−7·2	−5·0
	26	10	−0·97	−0·32	−3·5	−2·0
	28	12	−0·73	−0·09	−0·9	−1·3
	30	14	−0·83	−0·24	−1·4	−3·1
	31	15	−0·71	−0·17	+5·4	+2·9
June	1	16	−0·66	−0·17	+0·9	−2·2
	4	18	−0·85	−0·40	+4·5	+0·6
	7	21	−0·83	−0·31	+4·4	+0·6
June	15	2	−1·01	−0·22	−1·2	−0·2
	16	3	−0·84	−0·03	−1·7	+0·3
	17	4			−2·1	+0·6
	18	5	−1·02	−0·18	−5·3	−2·1
	19	5	−0·98	−0·13	−4·6	−1·1

Date 1915.		Errors of R.A.		Errors of N.P.D.	
		N.A.	Delaunay.	*N.A.*	Delaunay.
d	h	s	s	″	″
June 20	6	−0·89	−0·02	−5·4	−2·2
21	7	−1·06	−0·19	−5·8	−2·9
22	8	−1·15	−0·31	−5·5	−3·1
30	16	−0·66	−0·22	+4·1	+0·9
July 1	16	−0·74	−0·31	+2·3	−1·1
2	17	−0·82	−0·37	+4·9	+1·5
3	18	−0·48	−0·02	+4·5	+1·0
5	19	−1·13	−0·61	+2·1	−0·9
July 19	6	−0·84	+0·06	−4·3	−1·8
20	6	−1·14	−0·21	−3·5	−1·4
23	10	−1·10	−0·28	−1·5	−2·7
24	10	−0·99	−0·27	+0·4	−2·0
26	13	−0·87	−0·32	+3·1	−0·7
27	13	−0·88	−0·39	+5·3	+1·5
28	14	−0·65	−0·20	+3·5	+0·1
29	15	−0·64	−0·21	+4·5	+1·3
30	16	−0·58	−0·16	+3·8	+0·8
31	16	−0·70	−0·25	+2·2	−0·5
Aug. 1	17	−0·74	−0·26	+3·0	+0·5
3	19	−0·63	−0·10	+3·6	+1·9
4	20	−0·86	−0·28	−2·7	−4·0
Aug. 18	6	−1·05	−0·04	−2·8	−2·2
19	7	−1·14	−0·12	−0·7	−1·0
23	11	−0·86	−0·20	+4·8	+0·9
25	13	−0·69	−0·16	+3·2	−0·7
26	14	−0·62	−0·14	+4·2	+0·6
27	14	−0·65	−0·20	+4·6	+1·5
29	16	−0·86	−0·39	+2·3	0·0
Sept. 1	18	−0·96	−0·42	+2·6	+1·6
2	19	−0·95	−0·39	+6·4	+6·0
3	20	−0·95	−0·35	+2·2	+2·4
5	22	−1·06	−0·44	−4·4	−3·1
Sept. 16	6	−0·98	−0·11	+1·1	−0·2
17	7	−0·97	−0·06	+1·3	−0·6
19	9	−0·94	−0·13	+4·3	+0·5

Date 1915.		Errors of R.A.		Errors of N.P.D.	
		N.A.	Delaunay.	*N.A.*	Delaunay.
d	h	s	s	″	″
Sept. 20	10	−0·83	−0·11	+6·2	+2·0
21	11	−0·70	−0·06	+5·4	+1·0
24	13	−0·67	−0·15	+2·9	−0·8
25	14	−0·57	−0·07	+2·4	−0·7
27	15	−0·67	−0·18	+2·1	+0·1
30	18	−0·87	−0·38	−0·1	−0·5
Oct. 1	19	−0·98	−0·47	−0·6	−0·5
4	21	−1·09	−0·51	−6·1	−4·0
Oct. 14	5	−0·88	−0·22	−0·4	−2·8
15	6	−0·99	−0·33		
17	8	−0·83	−0·15	+4·7	+1·0
18	9	−0·77	−0·12	+4·4	0·0
20	10	−0·72	−0·14	+4·8	0·0
21	11	−0·79	−0·23	+4·1	−0·4
22	12	−0·76	−0·23	+4·8	+0·7
25	14	−0·80	−0·27	+1·8	−0·1
26	15	−0·82	−0·28	+0·5	−0·7
28	17	−0·82	−0·30	−1·4	−1·5
Nov. 1	20	−0·86	−0·30	−3·9	−1·6
2	20	−0·87	−0·27	−4·4	−1·6
Nov. 13	6	−0·87	−0·31	+4·5	+0·9
14	7	−0·82	−0·27	+5·0	+1·3
15	7	−0·79	−0·24	+3·9	0·0
16	8	−0·65	−0·09	+5·0	+0·8
19	10	−0·65	−0·10	+5·8	+2·1
26	16	−0·79	−0·26	−1·8	−1·2
Dec. 1	20	−0·84	−0·15	−5·8	−2·9
Dec. 10	4			+4·1	+0·3
11	5	−0·79	−0·18	+5·1	+0·8
12	5	−0·75	−0·17	+4·9	+0·6
13	6	−0·75	−0·19	+5·1	+1·1
21	12	−0·81	−0·22	−0·4	−1·1
27	17	−0·74	−0·20	−3·7	−2·6
29	18	−0·74	−0·13	−5·7	−4·2
30	19	−0·82	−0·15	−5·5	−3·7

The Relative Density of Stars with Proper Motions between certain limits in reference to their Galactic Latitudes. By Sir F. W. Dyson and W. G. Thackeray.

In the *Monthly Notices* for 1917 June a comparison was made of the relative densities of stars of different proper motions in different galactic latitudes from a consideration of the stars in Zone 24° – 32° N. dec. A similar comparison is now made for the stars of Boss's Preliminary General Catalogue, both for the interest in a comparison of bright stars with much fainter ones, and also because the proper motions of Boss's Catalogue are affected with very much smaller errors than the proper motions dealt with in Zone 24° – 32°.

Dividing the sky into bands of galactic latitude 0° to ±15°, ±15° to ±30°, ±30° to ±50°, and ±50° to ±90°, which give four regions of approximately equal area, the following table is obtained for the distribution of the proper motions of stars in different galactic latitudes :—

Number of Stars with Proper Motions between certain limits in different Galactic Latitudes.

Gal. Lat.	0″–1″.	1″–2″.	2″–3″.	3″–4″.	4″–5″.	5″–6″.	6″–7″.	7″–8″.	8″–9″.	9″–10″.	>10″.
+90° to +50°	15	43	51	45	39	36	40	41	29	21	199
+50° to +30°	27	53	99	79	74	59	52	37	35	30	197
+30° to +15°	44	82	103	91	100	49	42	24	21	27	165
+15° to + 0°	58	175	142	103	83	61	48	30	18	20	152
– 0° to –15°	128	233	163	131	89	55	30	28	17	24	145
–15° to –30°	78	117	127	97	60	59	35	21	24	26	176
–30° to –50°	28	85	71	74	60	49	50	36	25	24	204
–50° to –90°	21	61	67	64	45	55	42	27	27	22	194

The larger number of stars with proper motions >10″ a century in high galactic latitudes is attributable to the greater mean effect of star-streaming on these stars owing to the vertices being in the galaxy. The uniformity of the numbers in different galactic latitudes for proper motions >5″ and the progressive increase in the numbers of stars with proper motions <5″ a century, as the galaxy is approached, is very clearly shown.

The ratios of the numbers in galactic latitudes 0°–15°, 15°–30°, 30°–50°, compared with those round the galactic poles 50°–90°, are shown in the following table :—

Relative Star Densities.

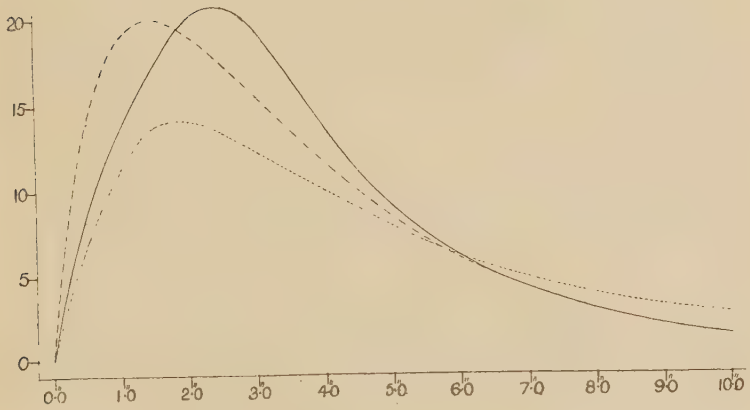
Gal. Lat.	0″–1″.	1″–2″.	2″–3″.	3″–4″.	4″–5″.	5″–6″.	6″–7″.	7″–8″.	8″–9″.	9″–10″.	>10″.
0° to +15°	5·8	4·1	2·8	2·3	2·1	1·7	1·2	0·7	0·6	0·9	0·7
+15° to +30°	2·9	1·9	2·0	2·0	2·6	1·4	1·0	0·6	0·7	1·4	0·8
+30° to +50°	1·8	1·2	1·9	1·8	1·9	1·6	1·3	0·9	1·2	1·4	1·0
0° to –15°	6·1	3·8	2·4	2·1	2·0	1·0	0·7	1·0	0·6	1·1	0·7
–15° to –30°	3·7	1·9	1·9	1·7	1·4	1·1	0·9	0·8	0·7	1·2	0·9
–30° to –50°	1·4	1·4	1·1	1·2	1·4	0·9	1·2	1·3	0·9	1·1	1·1

These results are in accordance with those given in *M.N.*, 1917 June, pp. 594–5, in showing that stars of sensible proper motion show a continual increase as the Milky Way is approached. This tendency is much greatest for stars of very small proper motion, but is well marked in the stars of proper motions $< 6''$ a century.

A comparison of the percentage of stars with different proper motions in Boss's Catalogue with that of the Greenwich Catalogue of Zone 24°–32° is given in the following table and in the accompanying diagram :—

Percentage of Stars with Proper Motions within certain limits.

Proper Motion.	Boss's Catalogue.	Greenwich Dec. 24°–32°	
		Observed.	Corrected.
$0''-1''$	7·0	8·2	14
1–2	13·8	17·5	20
2–3	13·4	20·7	16
3–4	11·1	16·6	14
4–5	9·0	11·0	10
5–6	6·9	6·9	
6–7	5·5	4·8	
7–8	4·0	3·3	
8–9	3·2	2·4	
9–10	3·2	1·5	
>10	23·4	7·1	



Boss's Catalogue . . . . . .
Greenwich Catalogue ———
Greenwich Catalogue, corrected – – – –

This comparison suggests generally the correction which the numbers obtained from the Greenwich Catalogue require on account of accidental error. The general effect of accidental error

has been to increase the percentage of stars with proper motions from 2″–5″ a century, and diminish the number from 0″–2″. The curve marked – – – – is a rough attempt to correct the numbers for the effect of accidental error.

The numbers given in *M.N.*, p. 594, are largely affected. But the ratios on p. 595, giving the relative density of stars of different proper motion in different galactic latitudes, are altered very little. There seems no reason to doubt the conclusion that the stars with proper motions less than 5″·0 a century show an increasing tendency to crowd towards the galaxy.

A 13th Magnitude Star in Centaurus, with the same Parallax as α Centauri. By J. Voûte.

In Circular No. 30 of the Union Observatory in Johannesburg, the discovery by Mr. Innes was announced of a faint star in Centaurus with about 5″ proper motion.

Its position is, for

1916·0 Ep. 1916·11 $14^h\ 23^m\ 54^s{\cdot}28$ $-62°\ 19'\ 10''{\cdot}1$,

measured from an astrophotographic plate, with reference to the two G.Z. Stars XIV. 1314 and XIV. 1396, near to it. As soon as more recent observations for comparison stars are available, a more accurate place can be given.

The star is near an 11·5 magnitude star. The differences in α and δ between the two stars have been observed as follows:—

1916·11	$\Delta\alpha = -26''{\cdot}06$	$\Delta\delta = -5''{\cdot}88$
1917·48	$= -31''{\cdot}09$	$= -4''{\cdot}74$

Assuming that the comparison star has no sensible p.m., we obtain for the star in question one year's p.m.:

$$\text{in } \alpha = -3''{\cdot}66, \qquad \text{in } \delta = +0''{\cdot}83.$$

The difference in magnitude photographically and visually is at least 2·5, viz. visually 11·0 and photographically 13·5. The star therefore must be reddish, and we may suggest it being of the Mb type.

The parallax has been determined by the same method as that described in *M.N.*, lxxvii., No. 2, for three southern binaries, but the full description will be given in the paper in which the whole photographic parallax work will be described.

Every plate gives an equation of condition between the relative shift of the star, its parallax and proper motion.

From four plates we get:—

$\pi = +0''.755 \pm 0''.028$. Relative mean magnitude comparison stars 11·4.

$\mu_a = -3''.67$. In good agreement with above determination.

The total motion is $3''.76$; $282°.7$.

Its magnitude, reduced to a distance of 10 parsecs., being 15·4 or 17·9 (visually or photographically), it may be considered at the present moment the faintest star known.

Now we have for α Centauri: p.m. $3''.68$, $281°.4$

$\pi = +0''.759$ (Gron. 24).

It will be seen that we get a result both as regards parallax and proper motion in close agreement with that of α Centauri, which is certainly interesting for two stars so far separated from each other (viz. 2° 12′).

Are they physically connected or members of the same drift?

Royal Observatory, Cape of Good Hope:
1917 *June* 27.

Photographic Magnitudes of B.D. + 56°.547. By C. Martin and H. C. Plummer.

1. In a former paper * the results of nearly four years' photographic observations of three variable stars in the region of χ Persei, made at Dunsink, have been communicated to the Society. Quite lately, in a letter dated 1917 June 16, Mr. J. Van der Bilt draws attention to the star B.D. + 56°.547, of which he has discovered the variability, with a reference to Harvard Bulletin, No. 625. On his suggestion this fourth variable has now been measured on the Dunsink plates, together with a set of four neighbouring comparison stars.

2. Details relating to the comparison stars are given in Table I. The magnitudes of these four stars for two plates are based on

Table I.

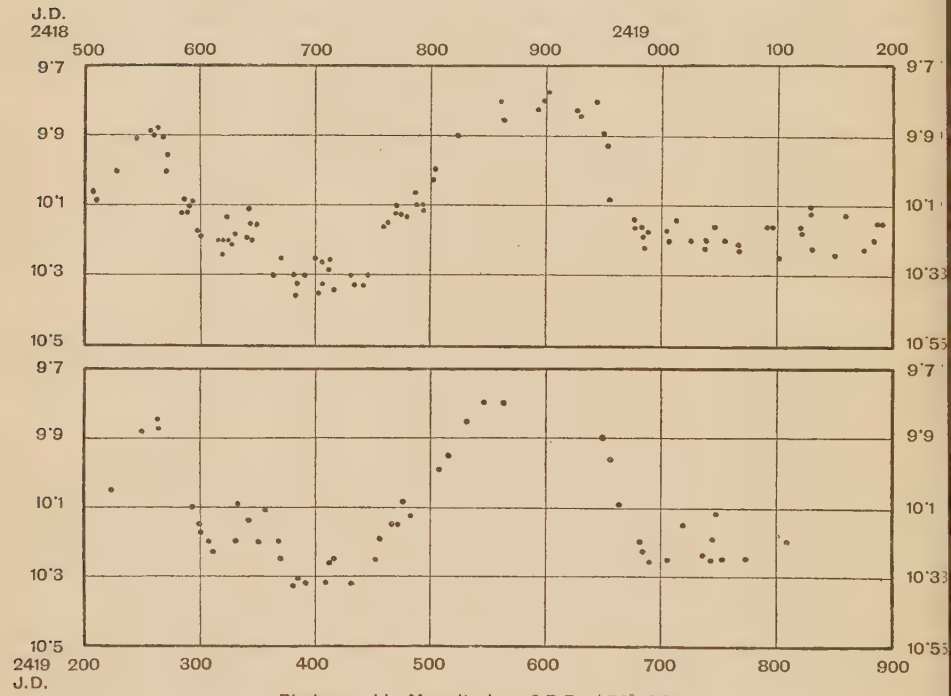
B.D. +56°.	Plate 4. m_1.	Plate 6. m_2.	$m_2 - m_1$.	Provisional Phot.-Mag.	Corr.	Final Mag.	P.E.	Range.
534	9·90	9·88	−·02	9·89	+·004	9·89	±·013	·13
557	10·00	10·00	·00	10·00	−·003	10·00	±·011	·11
538	10·21	10·20	−·01	10·20	−·005	10·20	±·015	·16
540	10·39	10·36	−·03	10·38	+·006	10·39	±·014	·16

Schwarzschild's system for the region. The means given in the fifth column have been used in the reduction of the variable. The plate residuals furnish small mean corrections, and hence a set of final magnitudes, which differ so little from those first adopted as

* *M.N.*, lxxiv. p. 686.

to call for no revision of the work. The probable error refers to a single measure, and the extreme range in the residuals is set down in the last column.

3. The derived photographic magnitudes of B.D. + 56°.547 are given in Table II., together with the Julian date and decimal fraction. The serial number corresponds with that given in Table I. of the paper quoted, from which may be drawn, if desired, the calendar date and G.M.T. for the middle of each exposure and also the length of exposure. It will be noticed that one plate, pre-



Photographic Magnitudes of B.D. +56°. 547.

viously omitted, has been interpolated between Nos. 165 and 166. Also six plates not belonging to the earlier series have been added at the end. These are plates which have been exposed on the regions of other variables, but also on the region of χ Persei, for the purpose of establishing the magnitude scale.

4. With the exception of the results from the six plates last mentioned, all the magnitudes, covering a period of about 1300 days, are plotted in the diagram which illustrates this paper. The total range slightly exceeds half a magnitude (9·8 – 10·3). The three variables of the region, to which reference has been made, appear to be absolutely irregular. At first sight the present star, when the observations are plotted in one continuous strip, appears

to share this character, though its variations are more definite. The almost stationary phase in the interval J.D. 2419,000 – 200 then suggests a resemblance to SS Cygni, in spite of the relatively small range. But on closer inspection a fact appears which is readily perceived when the record is presented in two consecutive sections of 700 days. In the second interval the star is repeating very faithfully the sequence of changes recorded in the first interval. To all appearance the variations are periodic, and follow a cycle of very approximately 700 days.

TABLE II.

Serial No.	Julian Day.	Magn.	Serial No.	Julian Day.	Magn.	Serial No.	Julian Day.	Magn.
	2418		45	682·35	10·30	87	901·50	9·77
3	507·54	10·06	46	683·35	10·36	88	928·43	9·83
4	510·51	10·08	47	684·36	10·32	89	930·39	9·84
5	528·52	10·00	48	691·37	10·30	90	944·38	9·80
6	544·54	9·91	51	701·34	10·25	91	950·38	9·89
7	557·47	9·88	52	703·44	10·35	92	952·34	9·93
8	560·44	9·89	53	705·35	10·26	93	956·40	10·08
9	563·41	9·87	54	706·35	10·33	94	977·34	10·14
10	567·45	9·90	55	711·31	10·28	95	978·37	10·16
11	570·49	10·00	56	713·30	10·25	97	981·41	10·16
12	572·46	9·95	58	717·51	10·34	98	983·36	10·19
13	585·33	10·12	60	731·46	10·30	99	985·32	10·22
14	586·38	10·08	61	735·40	10·32	100	987·32	10·17
15	588·42	10·12	62	741·46	10·33		2419	
16	591·40	10·10	64	746·46	10·30	101	004·33	10·17
17	593·39	10·09	67	760·38	10·16	102	005·32	10·20
18	598·39	10·17	70	763·40	10·15	103	012·28	10·14
19	600·38	10·18	72	770·42	10·12	104	026·43	10·20
25	617·33	10·20	73	771·42	10·10	105	038·42	10·22
26	618·31	10·20	74	772·43	10·12	106	039·42	10·20
27	620·30	10·24	75	778·45	10·13	107	046·34	10·16
28	621·32	10·20	76	788·42	10·06	108	055·42	10·20
29	623·48	10·13	77	790·42	10·10	109	067·34	10·21
31	627·34	10·21	78	791·46	10·10	110	068·34	10·23
32	631·30	10·18	79	795·54	10·11	111	091·35	10·16
35	641·27	10·19	80	802·59	10·03	112	096·45	10·16
36	642·30	10·11	81	803·57	9·99	113	102·46	10·25
37	644·47	10·15	82	823·53	9·90	114	120·41	10·16
38	645·29	10·20	83	861·54	9·80	115	121·42	10·17
40	649·27	10·15	84	864·54	9·85	116	129·40	10·12
42	664·40	10·30	85	893·50	9·82	117	129·42	10·10
43	672·26	10·25	86	899·45	9·80	118	130·40	10·22

TABLE II.—*continued.*

Serial No.	Julian Day.	Magn.	Serial No.	Julian Day.	Magn.	Serial No.	Julian Day.	Magn.
119	150·40	10·24	142	371·66	10·25	163	664·43	10·09
121	160·49	10·13	143	382·41	10·33	164	683·42	10·20
123	175·51	10·23	144	386·42	10·31	165	685·41	10·23
124	184·53	10·20	145	393·52	10·32	...	690 52	10·26
125	186·49	10·15	146	410·37	10·32	166	707·43	10·25
126	188·49	10·15	147	413·33	10·26	168	720·40	10·15
127	224·51	10·05	148	416 51	10·25	169	737·49	10·24
128	250·52	9·88	149	432·30	10·32	170	743·34	10·25
129	263·44	9·85	150	453·42	10·25	171	746·56	10·19
130	264·43	9·87	151	456·36	10·19	172	748·55	10·12
131	294·44	10·10	152	468·38	10·15	173	753·43	10·25
132	300·41	10·15	153	470·41	10·15	175	773·52	10·25
133	301·40	10·17	154	477·43	10·08	176	809·32	10·20
134	308·35	10·20	155	483·37	10·13		2420	
135	313·39	10·23	156	509·40	9·99	...	064·39	10·17
136	333·39	10·20	157	516·42	9·95	...	065·37	10·13
137	334·64	10·09	158	532·49	9·85	...	210·38	10·07
138	343·40	10·14	159	547·52	9·80	...	216·38	10·00
139	351·35	10·20	160	565·54	9·80	...	369·51	10·02
140	357·28	10·11	161	651·51	9·90	...	425·37	10·22
141	369·69	10·20	162	657·51	9·96			

5. The star appears then to be one of quite peculiar interest. By identifying the more salient features of the curve in the two successive cycles a period of 702 days was obtained. The material is insufficient for a much closer estimate. In order to extend the period of observation and to confirm the nature of the variation, the six plates at the end of Table II. were brought in. When the six magnitudes are antedated by 1400 days and plotted on the upper section of the diagram, they conform perfectly with the general run of the earlier magnitudes—so well, indeed, that it is difficult to deduce from their positions any decided correction to the above period. If anything, they seem to fall a little late, and suggest that the period is rather more than 700 days. The elements of principal maximum may be taken to be :

$$\text{J.D. } 2418\,884 + 704\,E.$$

Some little time must elapse before any considerable improvement on these elements can be expected, but Mr. Van der Bilt is already in possession of later observations.

6. Table III. contains some information relative to the four known variables in the region of χ Persei. None of them in any way resembles the cluster type. The visual magnitudes in the table

are taken from the A.G. Catalogue, and are compared with the mean photographic magnitude in deriving the colour indices. The latter must therefore be regarded as merely rough estimates. But the inference is tolerably plain that all these stars are very red.

Table III.

B.D.	A.G.C. (Helsingfors-Gotha).	Mag. (visual).	Mag. (photographic).	Colour index.
+56°·551	2131	7·8	9·8 – 10·5	+2·3
583	2166	8·5	9·9 – 11·2	+2·1
55 ·597	2160	7·7	9·2 – 10·3	+2·1
56 ·547	2120	7·2	9·8 – 10·3	+2·8

Mr. Van der Bilt suggests in his letter that the fourth star may be found to resemble the three stars already discussed at Dunsink. In physical condition it probably does so. But in type of variation there appears to be a difference. The three stars vary in that irregular way which is probably characteristic to a greater or less extent of all very red stars. If now the regular variation in a periodic cycle (which was entirely unexpected) be confirmed in a star presumably in a similar physical condition—the assumption may be unjustified, of course,—we may see here an interesting link between the regular and irregular types.

7. The curve is evidently complex, and its details cannot easily be represented by a formula. Nevertheless its main outline is given by the very simple equation

$$m = 10{\cdot}09 - 0{\cdot}095\ (\cos\theta + 2\cos 2\theta),$$

where $\theta = 0$ corresponds to the above principal maximum. To obtain a closer approach to the curve it is necessary to add a number of higher harmonics, none of which exceeds 0·035 in amplitude.

Dunsink Observatory:
1917 *Aug.* 14.

On the Spiral Nebula, M 51, *Canum Venaticorum.*
By Professor L. Becker, Ph.D.

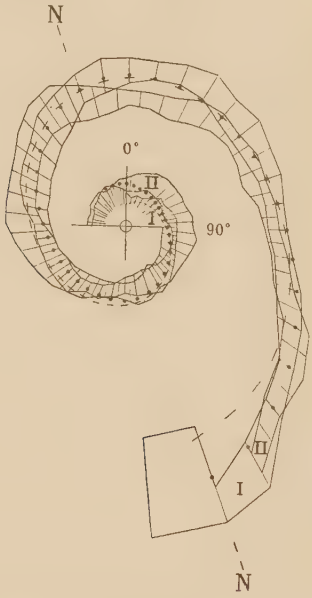
1. The accompanying diagram is the result of measurements of the photograph of the Spiral Nebula, M 51, as printed on plate xxix. in the publications of the Yerkes Observatory of the University of Chicago, vol. ii., one of the spirals (No. II.) being turned 180° in the diagram.

The measuring apparatus employed permits of the measurement of polar co-ordinates. The central condensation of the photograph was carefully centred with reference to the centre of rotation of the measuring slide, and the distances of the outlines of the two spirals (I. and II.) were measured at every tenth degree in position-angle.

Let p (0° to 520°) designate the position-angle of a point on Spiral I. as counted from an arbitrary zero, and let R_I and R_{II} be the scale readings of two corresponding and diametrically opposite points on the two spirals. I find from these figures that

$$\tfrac{1}{2}(R_I + R_{II}) = R_0 + v,$$

where R_0 differs from a constant value by 1·2 sin $(2p - 220°)$. This periodic term, whose amplitude is given in unit of 0·01 inch and is about a sixteenth of the diameter of the central condensation, must be due to the measuring machine. The diagram is



drawn with the distances $\rho_I = R_I - R_0$ and $\rho_{II} = R_0 - R_{II}$, Spiral II. being turned 180°. The distances between the two spirals equal $2v$, and these departures are of the order of the irregularities occurring in the outlines of the spirals. It may be said that the two spirals show the same tendency, and may be considered identical apart from accidental differences.

The table contains, under the heading "Observed Middle Curve," the arithmetic mean of the distances belonging to inner and outer outline.

2. I calculate $\frac{1}{2}(\rho_I + \rho_{II})$ for both inner and outer outlines and their means, ρ. Obviously ρ is independent of the adopted values of R_0. The average spiral as represented by ρ is the apparent spiral, and it is the projection of the real spiral on our reference plane drawn at right angles to the line of sight. The distances, ρ, of the apparent spiral generally increase with the position-angle, p,

though at some places they actually decrease with p. The observed distances may be represented by a power series in p, but evidently a large number of terms will be required so as to make the differential quotient by p to vanish at many values of p. The difficulty may be the effect of projection.

Consider three points of the real spiral, 180° apart in position-angle, and draw lines parallel to each other from these points to the line of sight that passes through the origin of ρ. Such lines can always be drawn even though the spiral is screw-shaped. The lengths of the lines are respectively r_p, r_{p+180}, r_{p+360}. The declinations of r_p and r_{p+360} are δ_p, and that of r_{p+180} is $-\delta_p$, the declinations being counted from the reference plane. Tentatively I then investigate whether the r_p may be so drawn that they are represented by a power series containing no higher power than p^2, while no assumption is made as to the relative position of the r_p at different values of p. Hence

$$r_p = x(1 + yp + zp^2),$$

$$r_{p+180}/r_p = \rho_{p+180} \sec \delta_p/\rho_p \sec \delta_p = \rho_{p+180}/\rho_p = M_p,$$

and further

$$ay + bz = n,$$

$$a = p + 180 - M_p p, \quad b = (p + 180)^2 - M_p p^2, \quad n = M_p - 1.$$

The 35 equations belonging to the values of p from 0° to 340° are solved by the method of least squares. The resulting values of y and z are then substituted, and the numerical values of $x \cos \delta_p$ are calculated for each value of p.

$$x \cos \delta_p = \rho_p/(1 + yp + zp^2).$$

The 52 values of $x \cos \delta_p$ turn out to be periodical in p, and show that the δ_p are the declinations of the points of a plane which is inclined to the reference plane. The longitude, N, of the node of the plane and its inclination, i, are

$$N = 160°, \quad i = 42°.$$

3. Though the power series in p satisfactorily represents the measured distances, I introduce an equivalent formula which is independent of the line of sight. Let l designate the longitude in the orbit, $l = N + u$, then

$$\tan u = \tan (p - N) \sec i \quad \text{and} \quad \tan \delta_p = \sin (p - N) \tan i,$$

$$r'_p = \rho'_p \sec \delta_p, \quad r_p = x'(1 + y'l + z'l^2).$$

The unknowns, x', y', z', are computed from 52 equations by the method of least squares. The result is, in units of 0·01 inch,

$$r_p = 13{\cdot}61 \pm 1{\cdot}15 + \frac{l}{500}(7{\cdot}42 \pm 5{\cdot}2) + \left(\frac{l}{500}\right)^2 (55{\cdot}3 \pm 4{\cdot}8);$$

or, since 1 mm. on the photograph represents 13″·2,

$$r_p = 44''{\cdot}9 \pm 4''{\cdot}0 + \left(\frac{l + 33^\circ \pm 24^\circ}{500}\right)^2 (185''{\cdot}4 \pm 16'').$$

The values of r_p and ρ_p (col. 5 in table) were calculated from these formulæ, and with them the curve is drawn which is marked by dots on the diagram. Of the 53 points, 31 points lie either within the space where the two spirals overlap or between the two spirals, 17 lie on Spiral I., and 5 on Spiral II. On the whole, the trend of the spirals appears to me to be satisfactorily reproduced by the dotted curve.

4. The results derived from the measurements may again be stated.

(1) The two spirals resemble each other, and corresponding points stand diametrically opposite to each other and equally far from a certain point near the middle of the condensation.

(2) Lines of length $r_p = a + bl^2$ may be drawn from the points of the real spiral to the line of sight that passes through the central point, defined under (1), and these lines, when displaced parallel to themselves to a point, all lie in a plane. The plane's longitude of node is 160°, and its inclination to the sphere is 42°.

I infer from the first result that the motion of the particles is outwards, for it is unlikely that particles coming from the outside would arrange themselves in the two spirals in an identical way.

The second result suggests that the longitude, l, may increase proportional to time, and that the formula for r does not only give the positions of the particles at the present time, but also the positions of a particle at any time. On this hypothesis a particle would be accelerated by a constant central force passing through the point to which the line r_p is drawn.

Such a constant force may be produced, as will be shown below, by the particles of a certain spheroid whose equator coincides with the plane of the nebula, and in which each particle acts according to the law of the inverse square of the distance.

The central force exerted by a homogeneous spheroid of density, D, on an exterior point situated on its equator at distance, r, from its centre is

$$\mathrm{R} = -c \cos\phi \sin^{-3}\phi(\psi - \tfrac{1}{2}\sin 2\psi)\mathrm{D}r,$$

in which ϕ is the angle of eccentricity, $2a$ the major axis, $\sin\psi = \sin\phi a/r$, and the constant, c, is positive for attraction and negative for repulsion. The force exerted on an interior point is represented by the same formula, provided ψ be changed into ϕ. Let now the density, D, change with the distance from the centre and be constant in each shell enclosed between two spheroids of the same eccentricity and major axes $2a$ and $2(a + da)$. The force exerted by the particles within the spheroidal space

on one of these particles which is situated on the equator at distance, r, is then found from the formula

$$R = \int_0^r D \frac{\partial(R/D)}{\partial a} da.$$

Assume $D = c'(a+\alpha)^{-k}$ where c', α, k have constant values and α is small compared with the distances, r, that have been measured.

$$R = -2cc' \cos\phi r^{-2} \int_0^r a^2(a+\alpha)^{-k}(1 - \sin\phi^2 a^2/r^2)^{-\frac{1}{2}} da.$$

This has a constant value for $k = 1$, as α is negligible compared with r. Hence, on the hypothesis that the longitude, l, increases proportionally to time, the dotted curve gives the position of the particles if they had been moving in a space filled with particles whose number per unit volume in each spheroidal shell is inversely proportional to $(a+\alpha)$.

5. I shall now investigate whether the spiral may also be satisfactorily represented on the assumption of another law of density of the particles. Taking $k = 3/2$, I have calculated the corresponding curve, and shown it in the diagram by a broken line. The formulæ may be derived in the following way. The formula for R becomes, with $k = 3/2$,

$$R = Cr^{-\frac{1}{2}},$$

where C is a positive constant for repulsion. The equation of motion is

$$\ddot{r} = Cr^{-\frac{1}{2}}.$$

The constant, H, in the integral of energy is positive and, therefore, also $G = 2C/H$ is a positive constant quantity. The integral becomes, if x be put for $Gr^{\frac{1}{2}}$ and c and t_0 designate constants,

$$c(t - t_0) = (x - 2)(1 + x)^{\frac{1}{2}} = X.$$

Let again the longitude, l, increase proportional to time, then

$$X = al + b.$$

With the object of finding the numerical value of G, I choose the numerical values of $r_1 = 10{\cdot}9$, $r_2 = 37{\cdot}1$, $r_3 = 90{\cdot}4$, belonging respectively to $l_1 = 6°$, $l_2 = 256°$, $l_3 = 506°$. The following equation must be satisfied:

$$F = 2(Gr_2^{\frac{1}{2}} - 2)(1 + Gr_2^{\frac{1}{2}}) - (Gr_1^{\frac{1}{2}} - 2)(1 + Gr_1^{\frac{1}{2}}) - (Gr_3^{\frac{1}{2}} - 2)(1 + Gr_3^{\frac{1}{2}}) = 0.$$

There is no positive root of this equation for G, because $F = 0$ for $G = 0$, and dF/dG is always positive for positive G. It follows that the three values of r cannot be perfectly represented on the above assumptions. A curve defined by the equations above can, however, be drawn near to the observed

curve. I choose arbitrarily G = 1, which value leads to as good a representation of the measurements as any of the other values tried. I then find the values of X for each observed value of r belonging to longitude, l, and hence the constants a and b by means of a graph of X with the abscissæ l. The graph is not a straight line, as it would be if the formula for D gave the actual density, but becomes steeper as l increases. I find $X = l18/520 + 1{\cdot}0$ and the inclination of the plane of the spiral $i = 35°$. The points of the broken line are calculated with these values, and the figures for their co-ordinates are given in the last two columns of the table. The broken line obviously does not represent the spiral satisfactorily at its beginning and end, and this might have been expected from the graph of X.

The adopted number per unit volume, $D = c(a+a)^{-1{\cdot}5}$, nearly agrees with that in the spirals if the particles of the spiral move according to the hypothesis stated in section 4, and keep between two parallel planes. For the space occupied by a given number, N, of particles is proportional to $r\dot{r}$, and therefore

$$D = cN/r\dot{r} = Cr^{-1}(r-e)^{-0{\cdot}5} = Cr^{-1{\cdot}5} \text{ nearly,}$$

as $r = e + fl^2$, $\dot{l} = n$, and e is small compared with r.

6. According to the last two sections, the central force which gives to a particle the required acceleration in a radial direction might be supplied by particles arranged in spheroidal shells containing a certain number of particles. This number per unit volume is nearly inversely proportional to the kth power of the major axis of a shell where k has a value near to unity and is certainly less than 1·5.

As to the uniform increase of the longitude with time, the particles may actually move at constant longitudes, and successive particles may start from the centre at regular intervals of time in directions which are turning round the centre at a uniform rate. Such conditions may happen when there are two bodies moving in eccentric orbits round each other, and a third body causing their periastron to move round at a nearly uniform rate. At and near to periastron great changes in the intensity of surface gravity may be conceived to occur, followed by eruptions. Conditions may prevail which are similar to those sometimes happening on the sun, and the deductions made by Arrhenius in the case of the sun* would also hold good here. Negatively charged particles would be emitted by both bodies and at points diametrically opposite to each other. After a stellar year the same process would repeat, but at a longitude slightly larger than at the preceding disturbance, in consequence of the secular perturbation of the periastron. These radially emitted particles would form the spirals. But, apart from them, particles also negatively charged leave the stars in all directions, and it may be these which supply the forces which propel the particles almost proportional to the square of time.

* Arrhenius, *Lehrbuch der kosmischen Physik*, part i., p. 150, etc.

	Observed Middle Curve.		Calculated. Section 3.		Section 5.	
p.	$\rho_{I.}$	$\rho_{II.}$	l.	ρ.	l.	ρ.
			°		°	
0	8·4	12·4	6·1	13·1	4·0	6·6
10	6·3	13·7	17·8	12·8	15·2	7·3
20	6·9	14·2	28·5	12·3	25·7	7·9
30	6·7	15·7	38·1	11·9	35·5	8·5
40	6·9	15·8	46·8	11·7	44·7	9·0
50	10·5	15·8	54·9	11·5	53·4	9·5
60	9·9	16·0	62·5	11·5	61·8	10·0
70	11·0	15·3	70·0	11·7	70·0	10·6
80	11·4	16·1	77·5	12·0	78·2	11·3
90	12·1	17·0	85·1	12·6	86·6	12·2
100	13·5	18·4	93·2	13·3	95·3	13·3
110	13·8	18·2	101·9	14·4	104·5	14·5
120	14·9	17·9	111·5	15·7	114·3	15·9
130	16·2	18·0	122·2	17·1	124·8	17·5
140	18·0	18·5	133·9	18·7	136·0	19·3
150	18·8	17·4	146·7	20·4	147·9	20·9
160	18·1	19·6	160·0	21·7	160·0	22·4
170	18·4	20·7	173·3	22·6	172·1	23·5
180	18·0	20·0	186·1	23·0	184·0	24·3
190	20·3	19·7	197·8	22·9	195·2	24·8
200	21·3	20·8	208·5	22·7	205·7	25·1
210	23·2	20·8	218·1	22·6	215·5	25·3
220	24·0	22·7	226·8	22·4	224·7	25·5
230	23·8	24·3	234·9	22·4	233·4	25·7
240	23·6	25·2	242·5	22·6	241·8	26·2
250	24·3	25·5	250·0	23·1	250·0	26·8
260	24·6	28·1	257·5	24·0	258·2	27·9
270	25·7	31·0	265·1	25·3	266·6	29·1
280	27·8	32·6	273·2	26·9	275·3	30·6
290	29·6	33·4	281·9	29·2	284·5	32·6
300	31·6	35·5	291·5	31·8	294·3	34·7
310	33·4	38·7	302·2	34·9	304·8	37·2
320	37·4	41·6	313·9	38·2	316·0	39·7
330	40·0	42·4	326·7	41·5	327·9	42·1
340	44·6	41·3	340·0	44·2	340·0	43·9
350	46·9	38·8	353·3	45·9	352·1	45·1
360	48·1	39·4	366·1	46·5	364·0	45·7
370	48·7	39·2	377·8	46·2	375·2	45·7
380	49·8	38·6	388·5	45·7	385·7	45·4
390	49·8	40·8	398·1	45·0	395·5	45·0
400	47·0	42·3	406·8	44·4	404·7	44·7
410	46·8	42·3	414·9	44·3	413·4	44·7
420	45·8	42·2	422·5	44·5	421·8	45·0
430	46·4	41·7	430·0	45·3	430·0	45·6
440	45·8	43·5	437·5	46·8	438·2	46·8

	Observed Middle Curve.		Calculated. Section 3.		Calculated. Section 5.	
p.	$\rho_{I.}$	$\rho_{II.}$	l.	ρ.	l.	ρ.
450	46·0	44·7	445°·1	49·0	446°·6	48·4
460	49·0	47·8	453·2	51·9	455·3	50·6
470	52·9	51·5	461·9	55·7	464·5	53·2
480	57·8	60·7	471·5	60·4	474·3	56·2
490	65·0	66·6	482·2	65·9	484·8	59·6
500	71·8	70·9	493·9	71·4	496·0	63·0
510	83·3	82·5	506·7	77·1	507·9	65·8
520	90·3	...	520·0	81·1	520·0	68·0

Note on the Latitude of Glasgow Observatory.
By Professor L. Becker, Ph.D.

In the years 1897 to 1907 I observed with the Transit Circle the pole star B.D. 89°. 37 whose daily orbit lies in the field of the telescope. The results of these observations are being published in the *Memoirs* of the Society.* I have explained there the method by which, without reference to the almanac positions of pole stars, the position of the true pole can be found from two or more observations of B.D. 89°. 37 taken during a night, and the interval in sidereal time between the observations. The interval was about three hours. These observations give finally the co-ordinates of the reference star, and herewith for each day the pole point, $(D)+dD$, of the circle, *i.e.* the circle reading when the telescope is directed towards the true pole. (D) stands for $N \pm (90^\circ + c)$ where N denotes the circle reading at the Nadir direction of the telescope, and c has the constant value 55° 52′ 42″·20. The upper sign belongs to the position of the axis when the circle lies towards the west, and the lower sign to the reversed position. The latitude, ϕ, on a certain day satisfies the relation, $\mp(90+\phi) = N + dN \pm w - (D) - dD$. Hence

$$\phi = c \pm dD \mp dN - w \quad . \quad . \quad . \quad . \quad (1)$$

dN is the unknown division error at the Nadir position, and it has the same value at both positions of the axis. $w = v_0 + v$, v_0 denoting systematic station errors and v the accidental errors.

Let further ϕ_0 be the geographical latitude referred to the "mean pole" on the earth's surface adopted in the publications of the International Latitude Service, and let the instantaneous pole on the earth's surface have the co-ordinate ξ along the axis drawn from the mean pole towards Glasgow. Hence

$$\phi = \phi_0 + \xi \quad . \quad . \quad . \quad . \quad (2)$$

$$\phi_0 = c \pm dD \mp dN - \xi - v_0 - v \quad . \quad . \quad . \quad (3)$$

* Vol. lxii.

The observations utilised here were taken on 79 days when the circle was placed on the west side, and on 74 days with circle east. They give $dN = +0''\cdot14$, and this value of dN was employed in correcting the dD according to formula (1). The accuracy of dD on a certain day depends on the number of points of the orbit of B.D. 89°.37 used in its determination. The adopted weight, p, is 1 for 1 point, 1·5 for 2 points, . . . and 3 for 5 points. The daily values of $\pm(d\mathrm{D} - dN)$ are combined in normal places which, together with their weights, p, are shown in the second and third columns of the table below. The values of ξ in the fourth column were obtained from the publications of the Zentralbureau der Internationalen Erdmessung. The fifth column contains the systematic errors v_0, which, if real, are probably not due to erroneous values of ξ, but to periodic changes in the direction of gravity. $v_0 = +0''\cdot14 \sin(\mathrm{L} + 217°)$, L being the longitude of the sun.

Year.	p.	$\pm(d\mathrm{D}-dN)$.	$-\xi$.	$-v_0$.	$-v$.
		″	″	″	″
1897·61	1·5	−0·45	−0·17	+0·01	−0·50
98·23	7	−1·06	+0·18	+0·09	−0·68
98·58	12·5	−0·17	−0·01	+0·04	−0·03
98·73	10·5	−0·03	−0·18	−0·09	−0·19
98·92	10·5	+0·27	−0·14	−0·13	+0·11
99·20	12·5	−0·03	+0·05	+0·07	+0·20
99·39	11·5	−0·36	+0·08	+0·14	−0·03
99·64	13	−0·03	+0·04	−0·02	+0·10
99·95	10	−0·01	−0·03	−0·12	−0·05
1900·12	12·5	+0·09	−0·06	0·00	+0·14
00·40	9·5	−0·49	+0·05	+0·14	−0·19
00·61	9	−0·04	+0·06	+0·01	+0·14
00·82	12·5	−0·16	+0·07	−0·13	−0·11
01·11	12	+0·23	−0·03	−0·01	+0·30
01·68	12	+0·36	−0·03	−0·05	+0·39
01·83	13·5	−0·04	+0·04	−0·14	−0·03
02·08	14·5	−0·28	+0·07	−0·04	−0·14
02·28	8	+0·08	−0·03	+0·12	+0·28
02·78	19	−0·12	−0·05	−0·12	−0·18
03·25	9	−0·61	+0·10	+0·10	−0·30
04·11	9	−0·45	+0·15	−0·01	−0·20
04·23	9·5	−0·63	+0·17	+0·09	−0·26
05·29	9	−0·24	+0·15	+0·13	+0·15
06·99	5	+0·06	−0·05	−0·10	+0·02

The mean latitude becomes $\phi_0 = 55°\ 52'\ 42''\cdot09 \pm 0''\cdot05$.

The sum of the squares of the residuals with regard to weight, $[pvv]$, is 21·8 for zero values of both ξ and v_0, 14·6 when v_0 is neglected, and 12·2 when both ξ and v_0 are taken into account.

LIST OF ADDITIONS

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